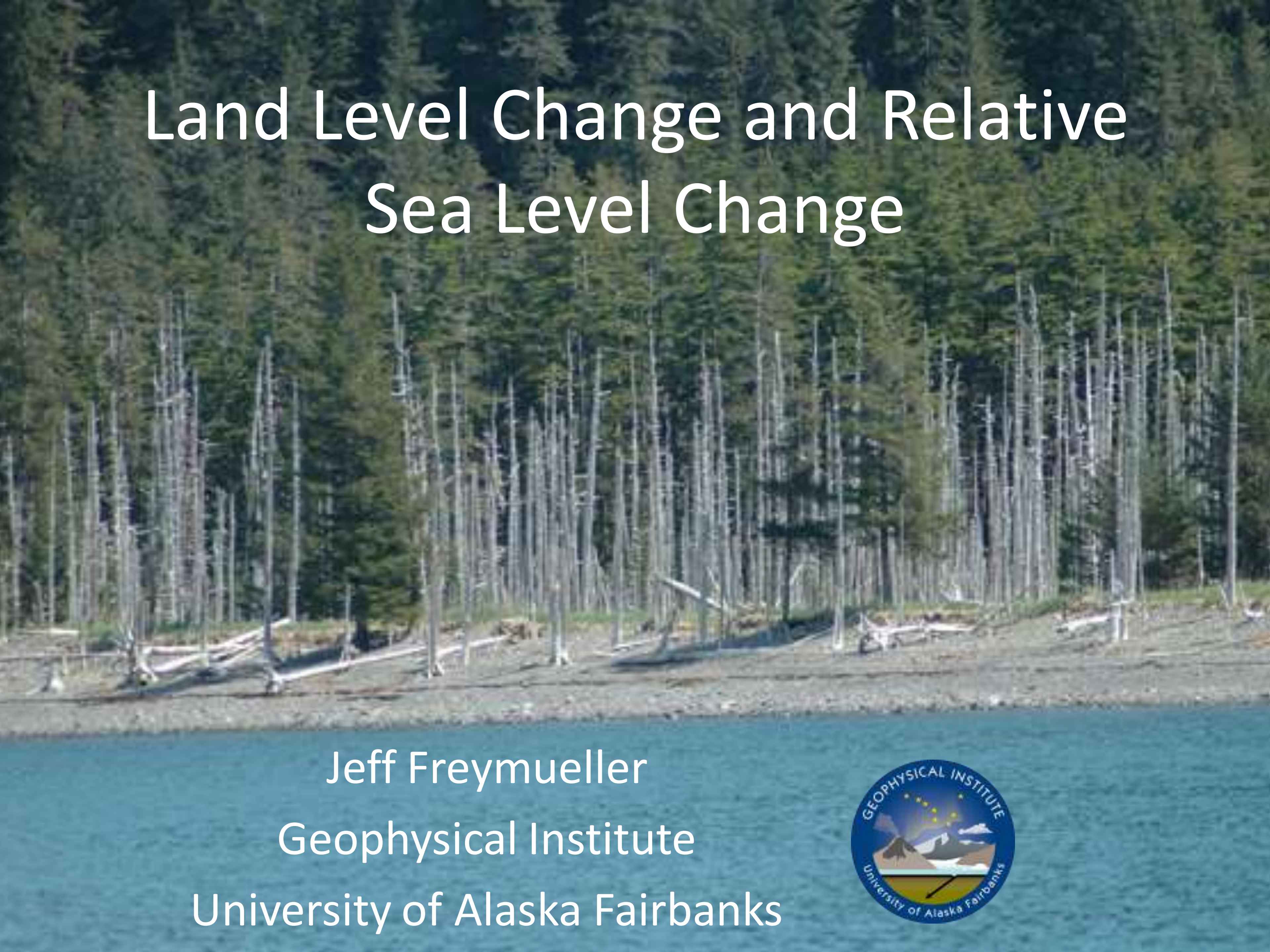


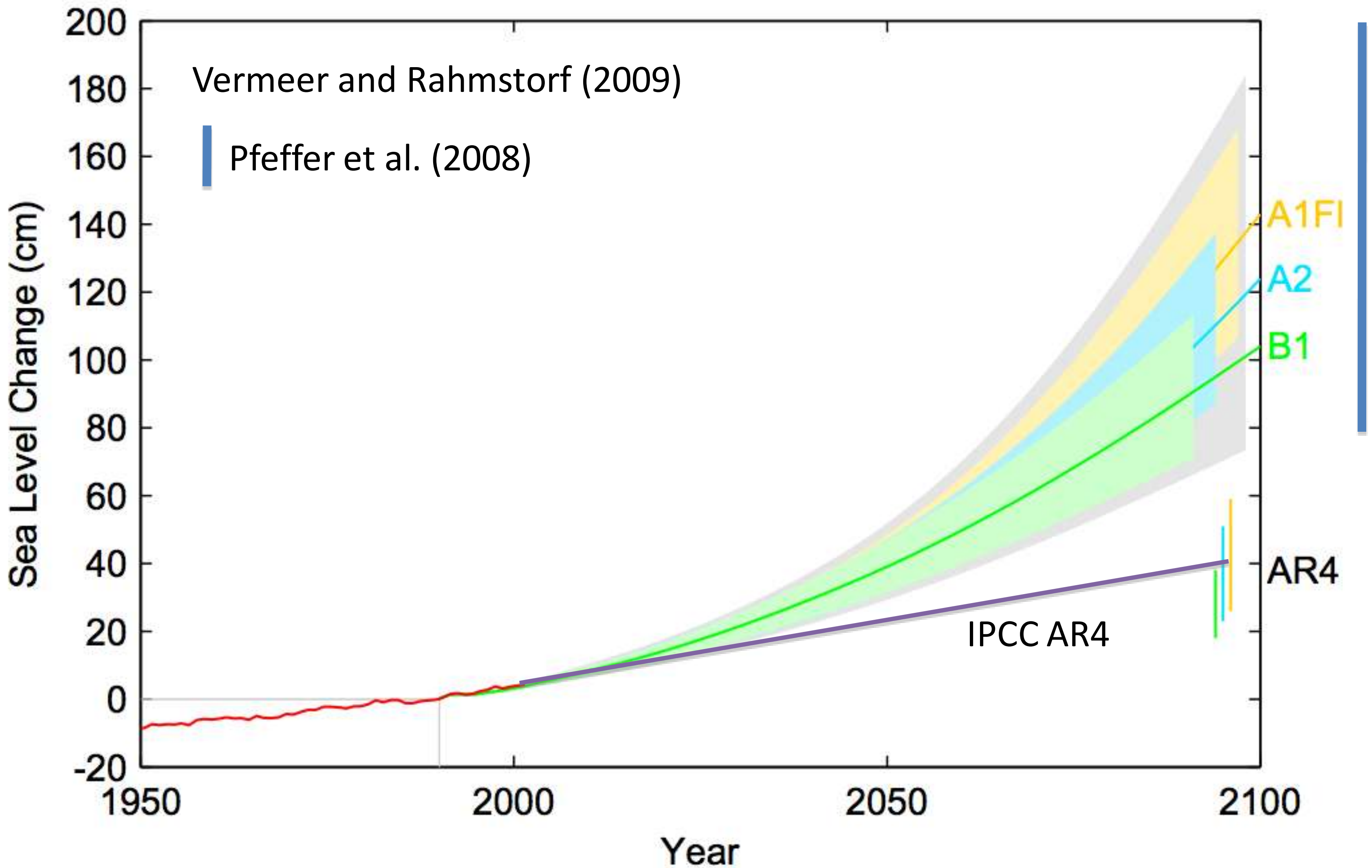
Land Level Change and Relative Sea Level Change

Jeff Freymueller
Geophysical Institute
University of Alaska Fairbanks

Take Home Messages

- Relative sea level is determined by both the level of the ocean and the level of the land
  - *The land surface in southern Alaska is moving faster than global sea level is presently changing*.
    - But rising sea level is likely to “catch up” eventually.
- We can measure these motions precisely
- We know the main causes of these motions
- We must extend models that explain horizontal motions to explain vertical motions.
  - Can we project motions decades into the future?

Predicted Global Average Sea Level

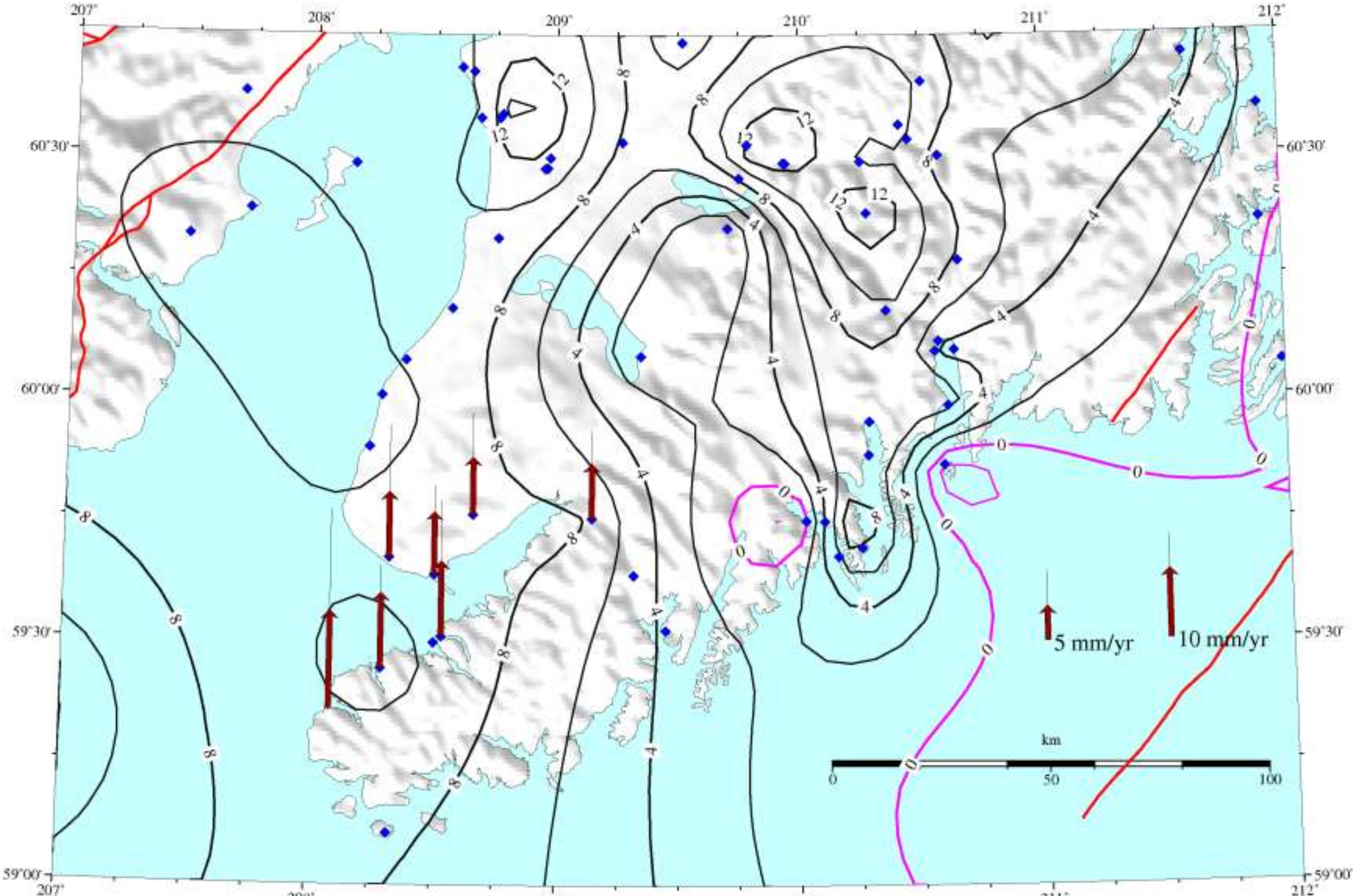


Relative Sea Level

Relative Sea Level

- RSL = ***level of the sea*** minus ***level of the land***
- Both terms can vary regionally
  - Level of the sea: thermal expansion, addition of water, **gravity field**, oceanography
  - Level of the land: **tectonics**, **post-glacial rebound**, **changes in water/ice loading**, **compaction of sediments**, etc.
- In Alaska, land level changes are, in general, more rapid than sea level changes.

Uplift Rates – Kenai Peninsula

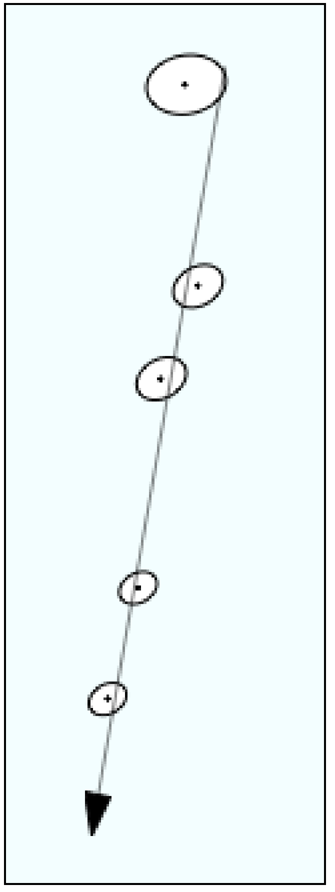


Global Positioning System

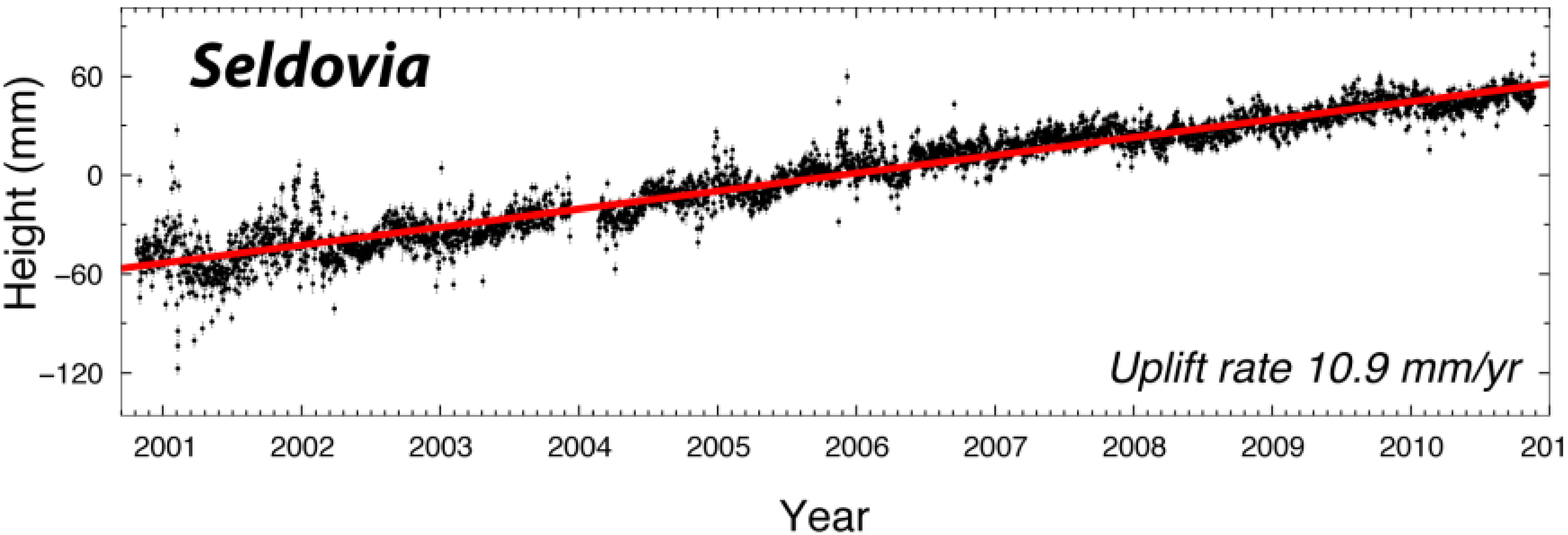
- Portable Surveying Equipment
- Precision of a few millimeters in 3D
- Repeated surveys measure motion of sites

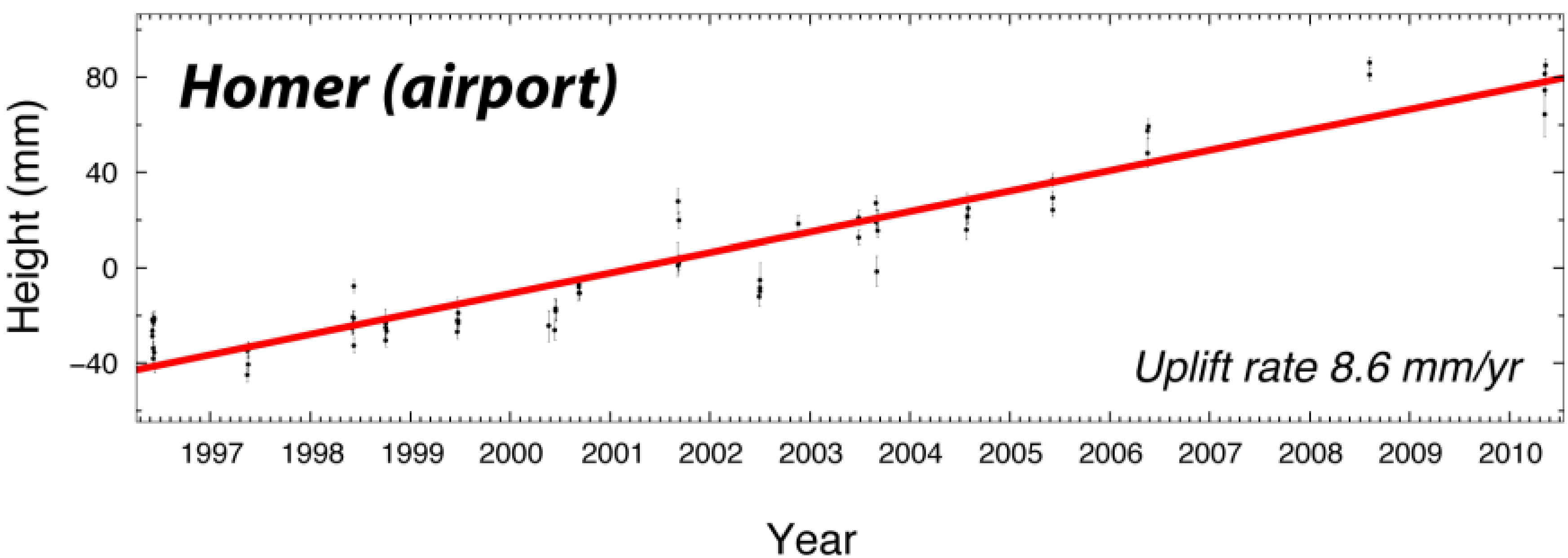
Measuring the Crust

- GPS surveys repeated over time
- Series of positions records the motion of a point fixed to the crust
  - Plate motion
  - Deformation
  - Measurement noise
- Three Dimensions!

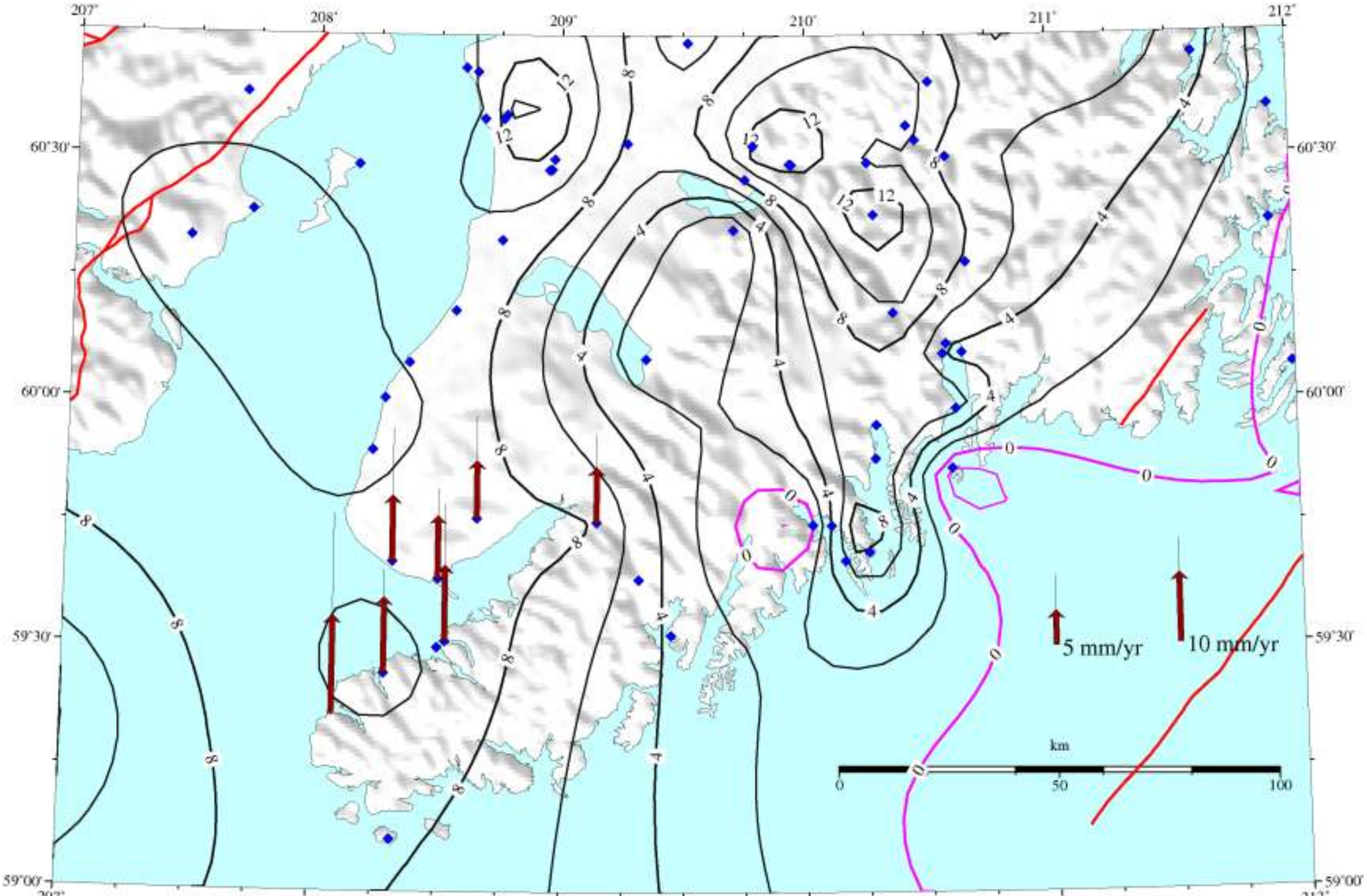


Vertical Time Series





Uplift Rates – Kenai Peninsula

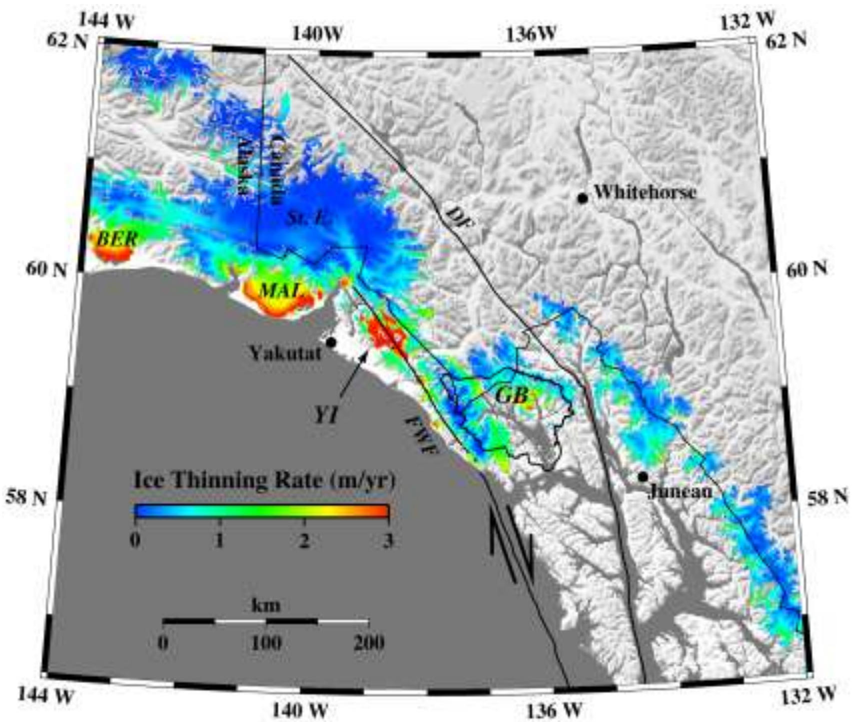


Main Causes of Uplift Locally

- Post-Glacial Rebound/Glacial Isostatic Adjustment
  - Uplift of the land caused by removal of ice load
    - Time-delayed (viscous) response due to past load changes
    - Instant (elastic) response due to ongoing load changes
- Tectonic effects
  - Uplift due to post-seismic deformation after 1964 earthquake
  - Deformation due to plate coupling at subduction zone

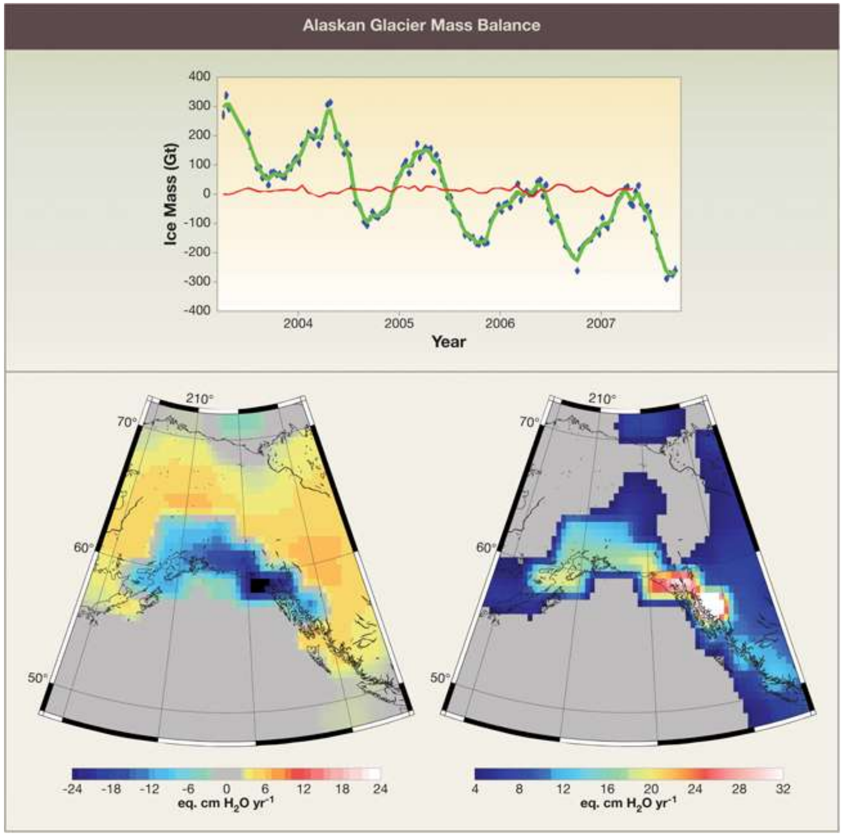
Post-Glacial Rebound – Melting Ice

From repeat glacial altimetry



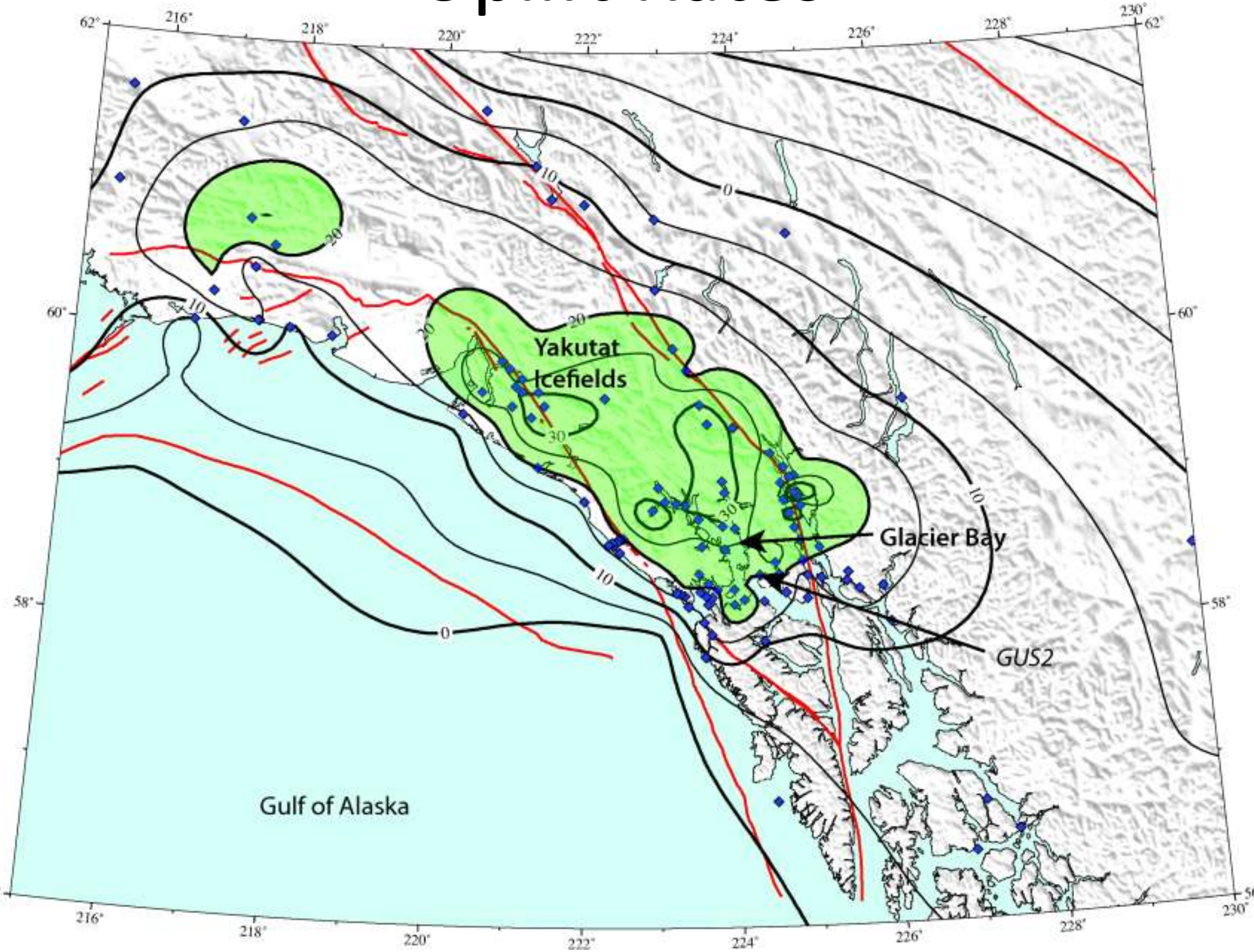
Arendt et al. (2002)

From geoid changes (GRACE)

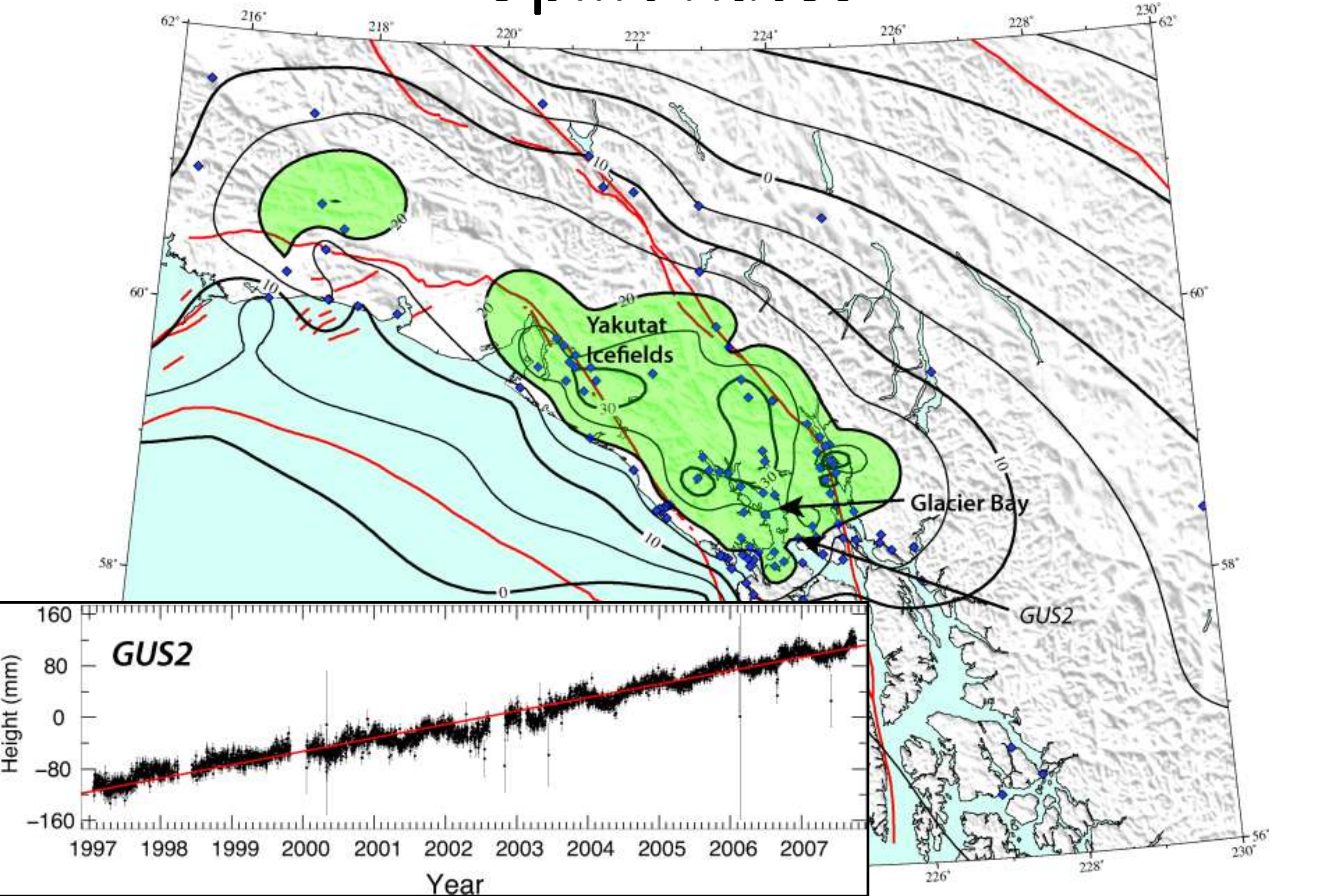


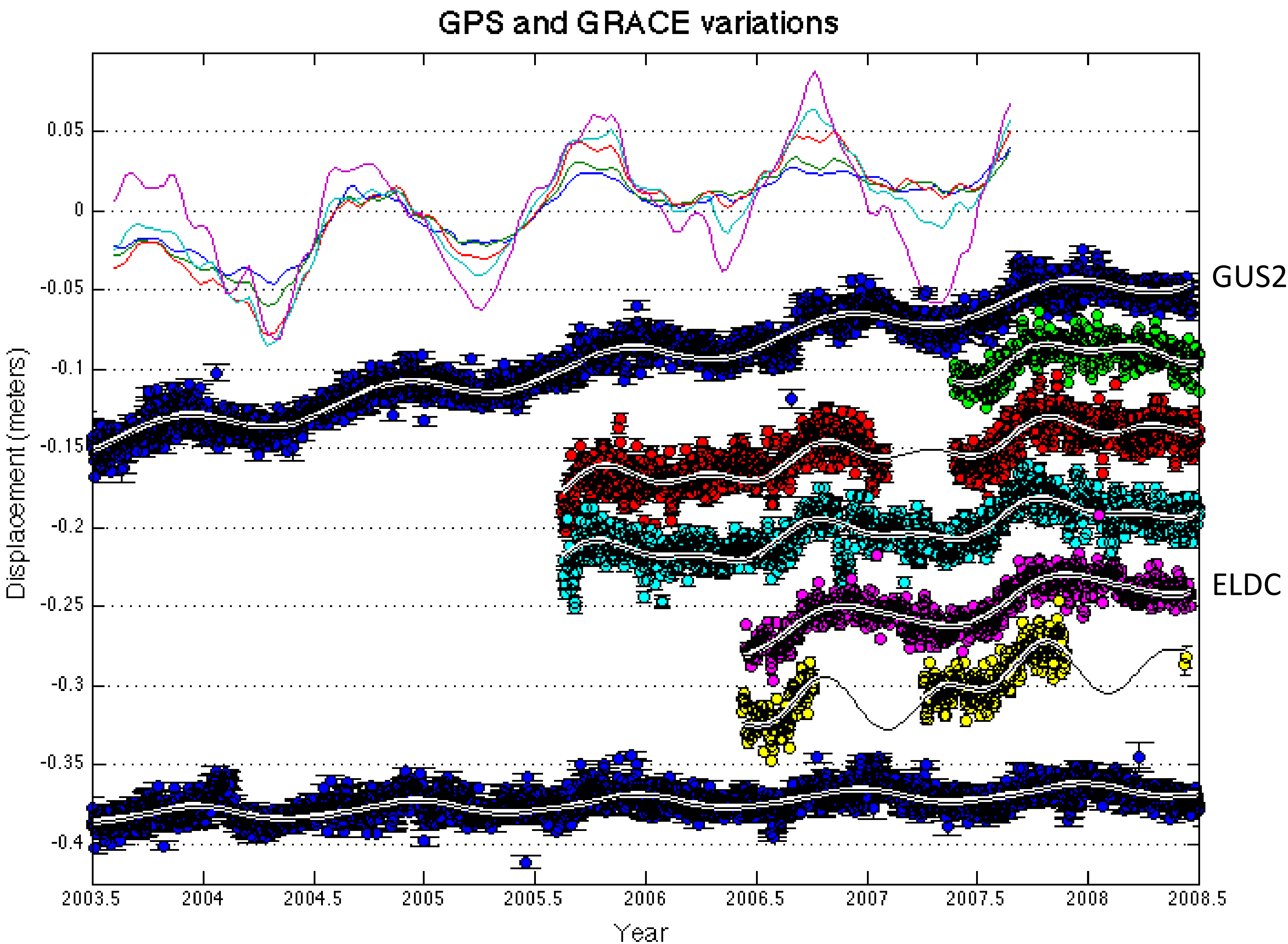
Luthcke et al. (2008)

Uplift Rates



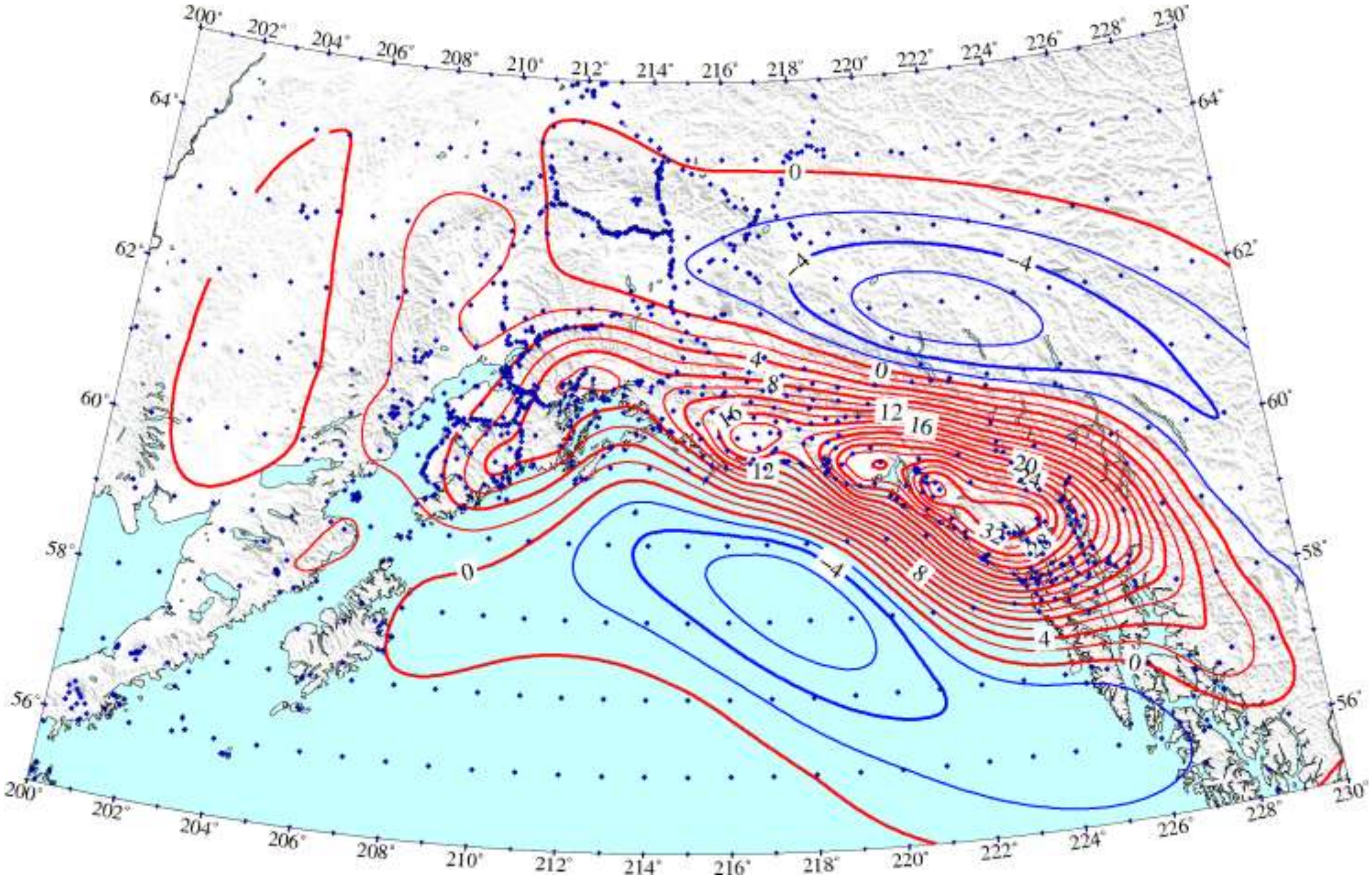
Uplift Rates





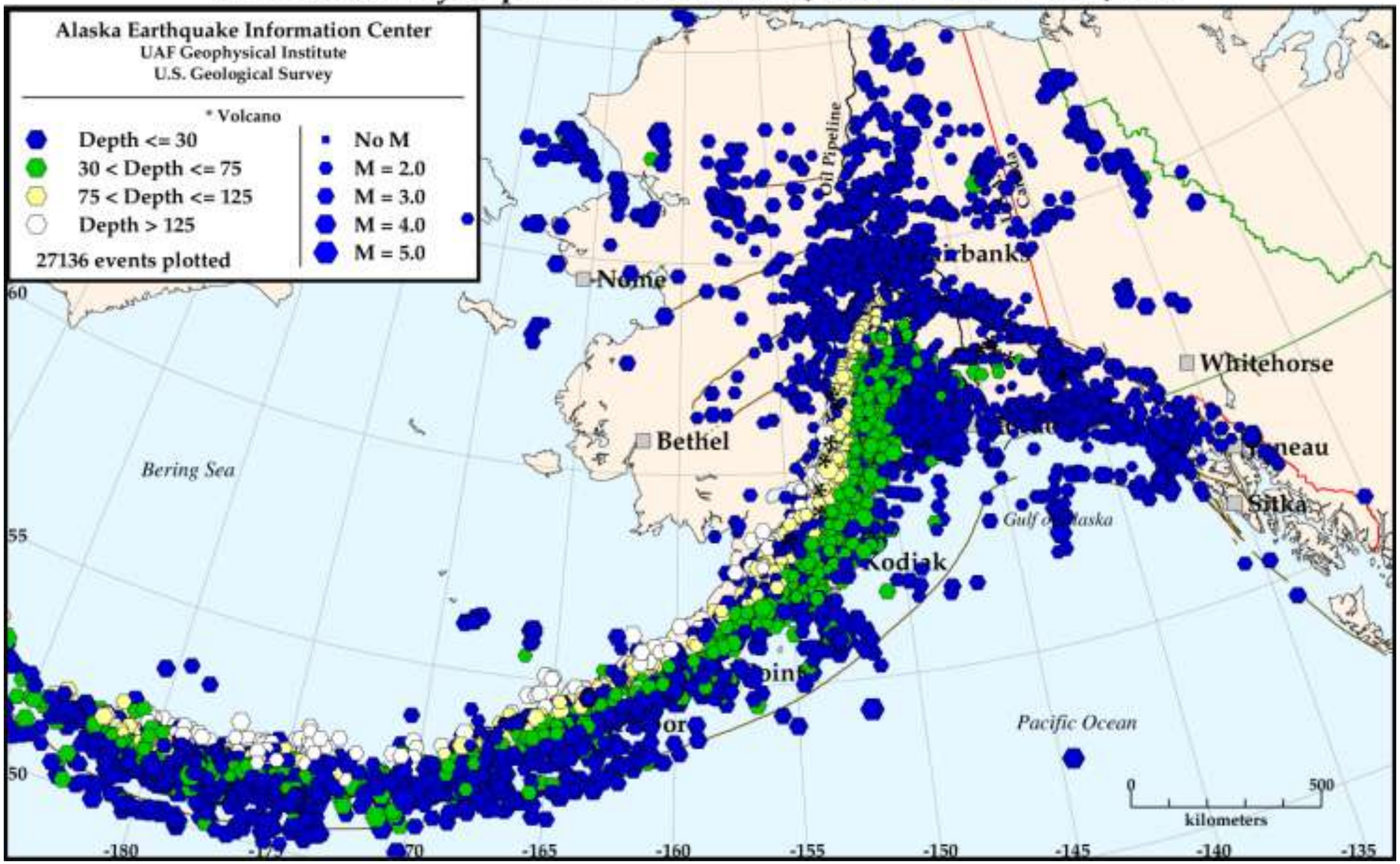
GPS and GRACE variations
Displacement (meters)
Year
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
2003.5
2004
2004.5
2005
2005.5
2006
2006.5
2007
2007.5
2008
2008.5
GUS2
ELDC

Predicted Uplift/Subsidence Rates

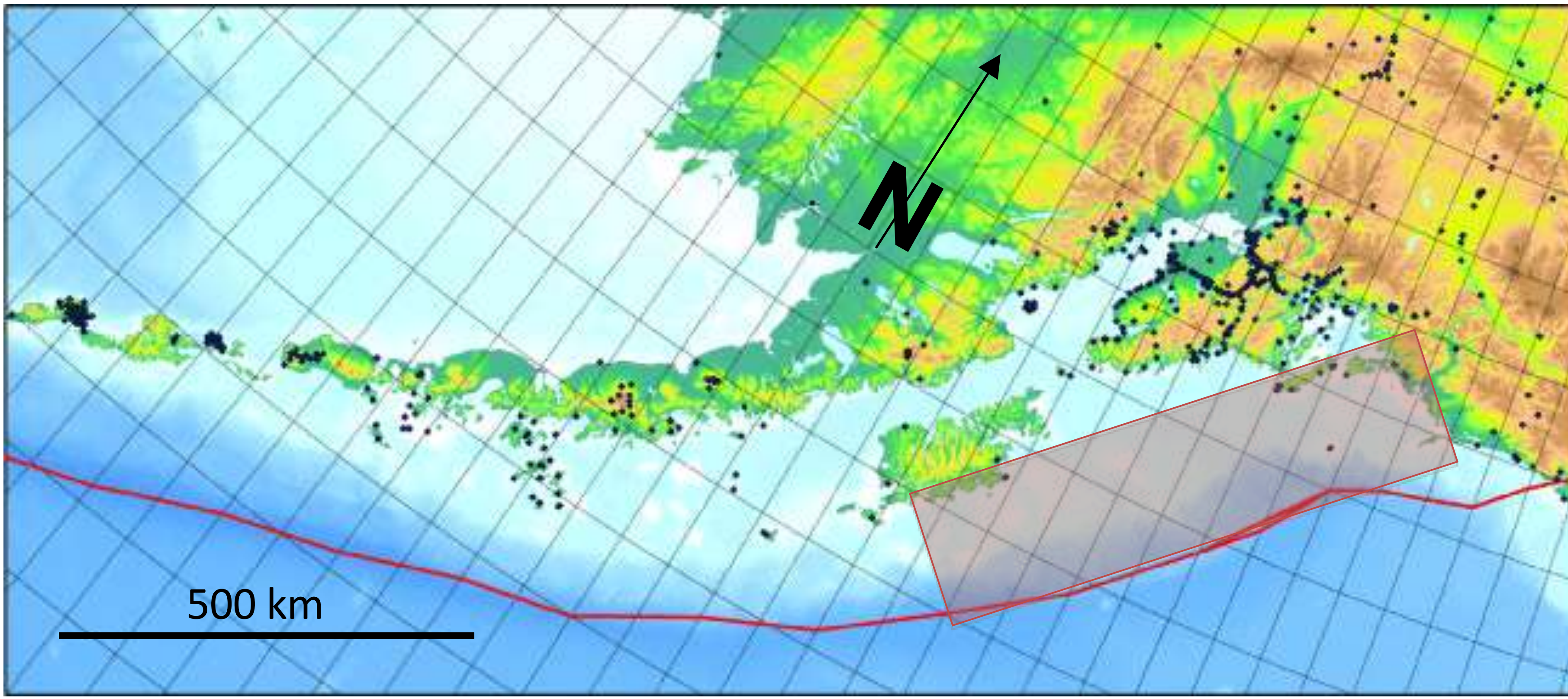


One Year’s Seismicity

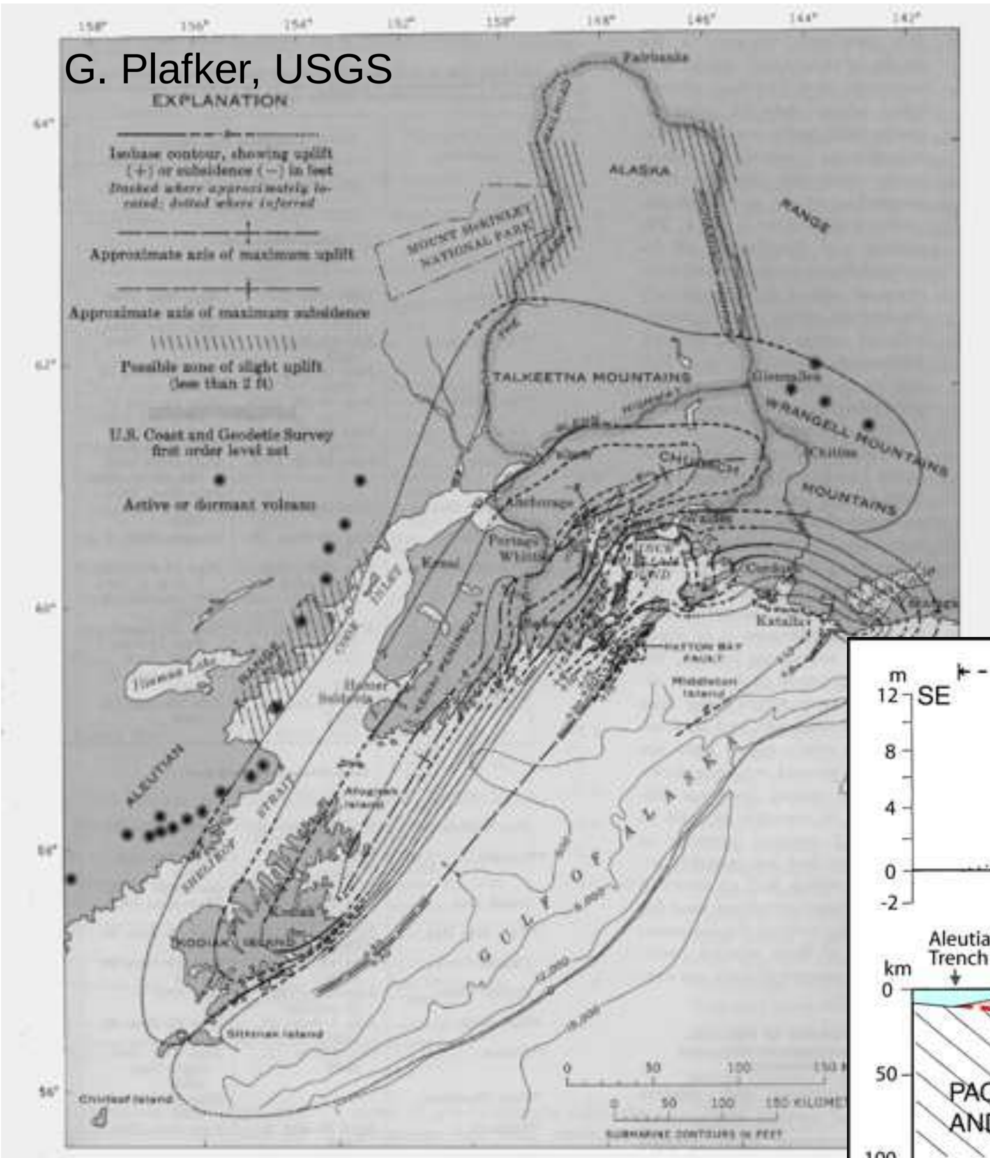
AEIC Seismicity Report for December 01, 2007 - November 15, 2008



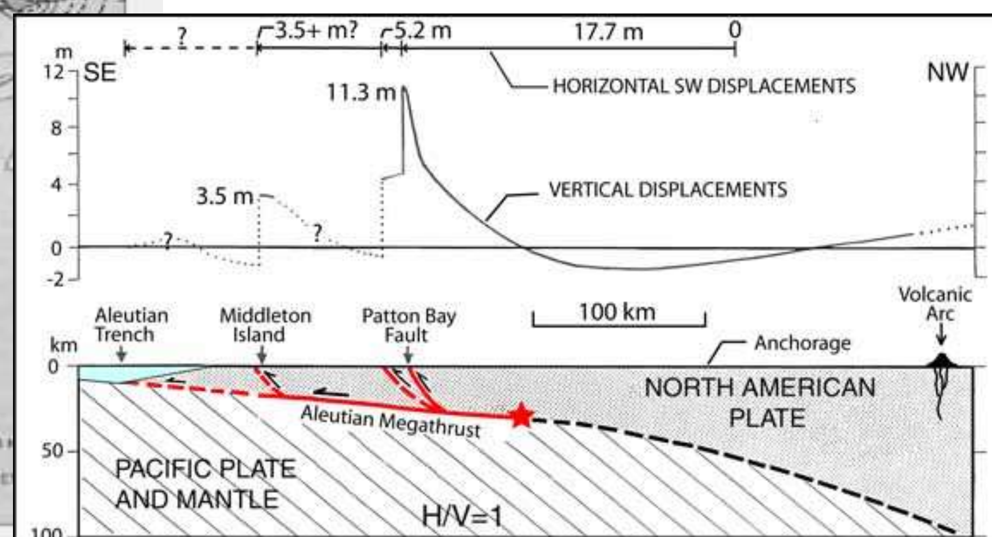
Tectonic and Earthquake Effects



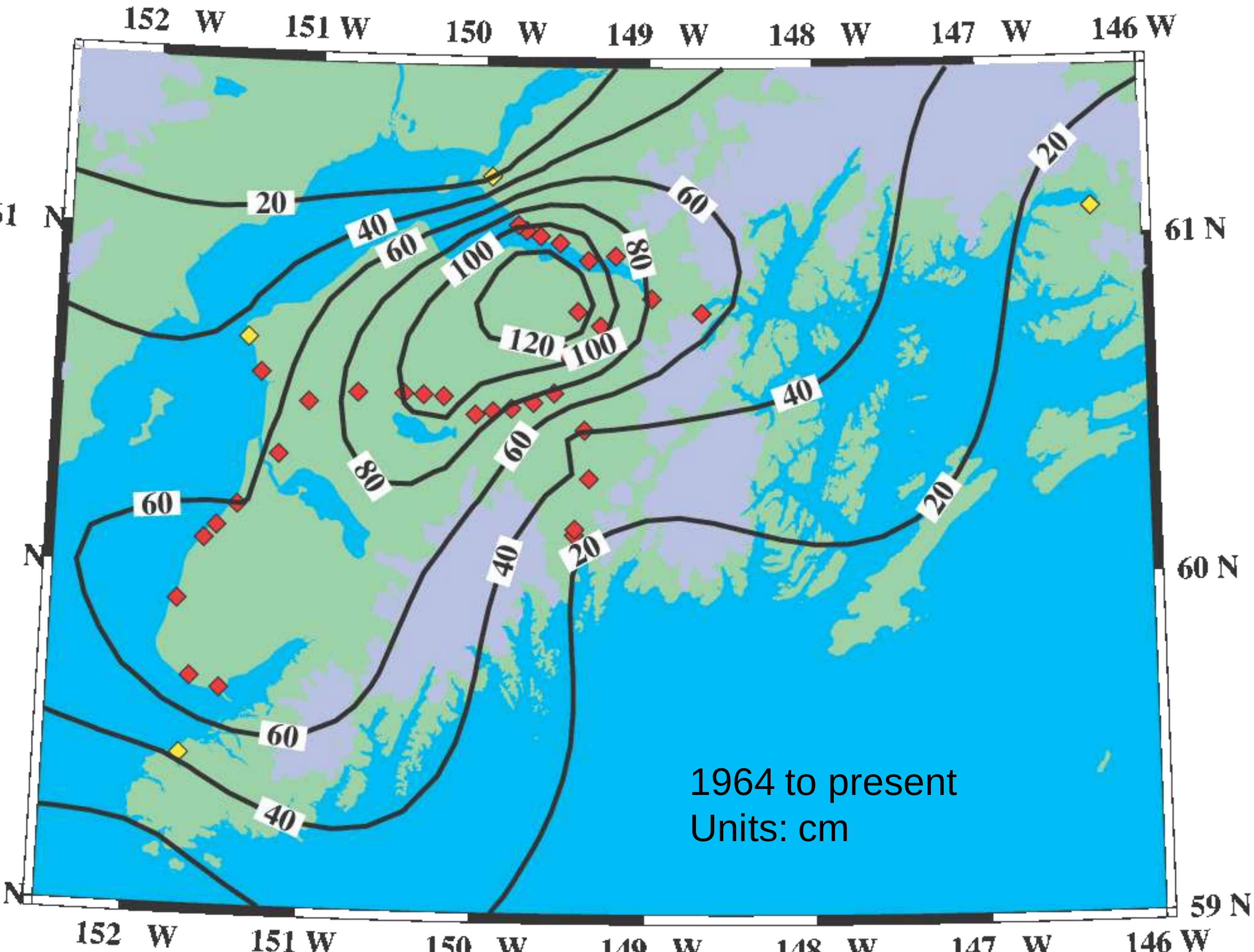
Subsidence in 1964



- Kachemak Bay lay near axis of maximum subsidence in 1964
- About 1 meter subsidence
- Cyclic pattern
  - Land here uplifts between earthquakes and subsides during earthquakes

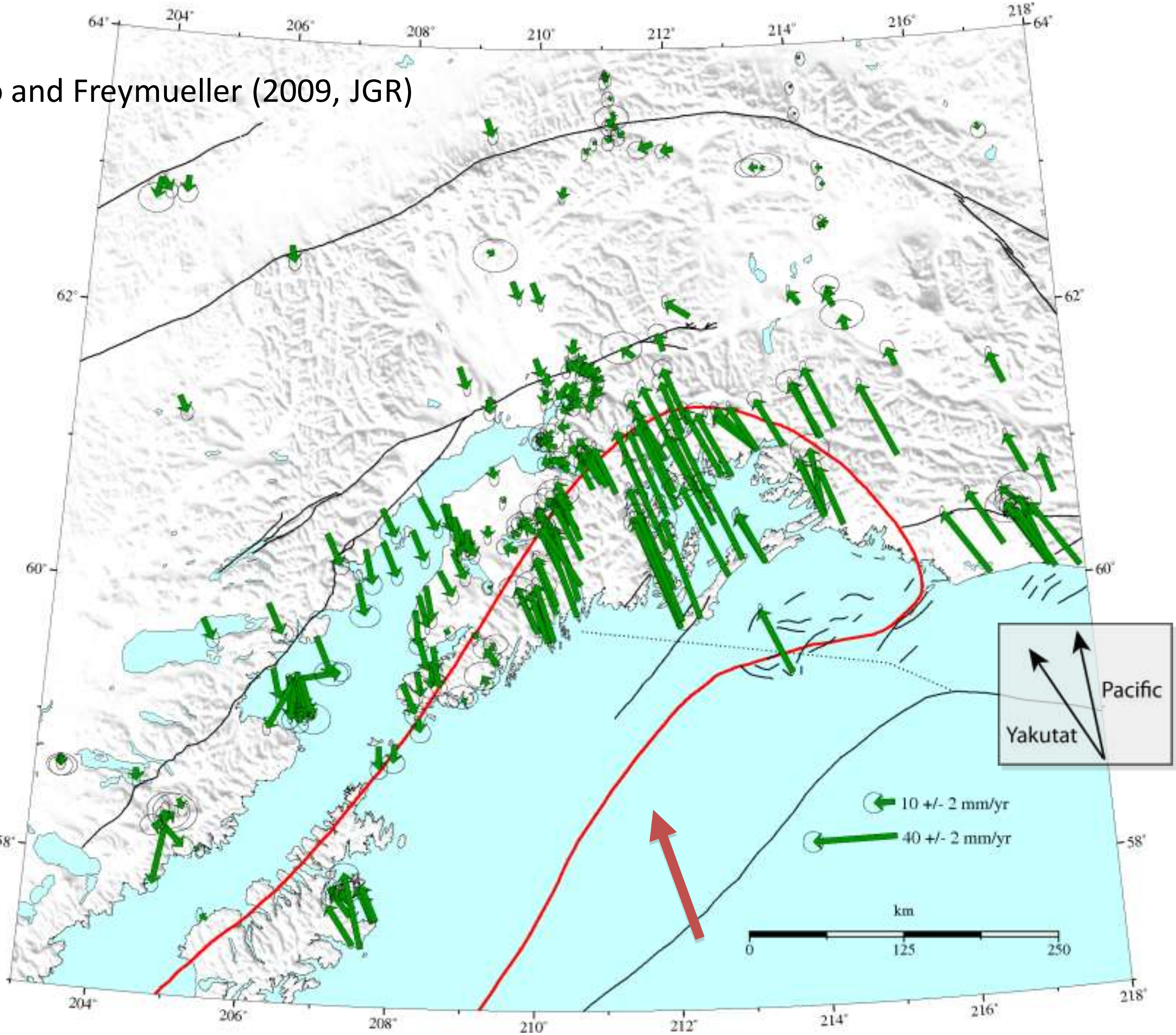


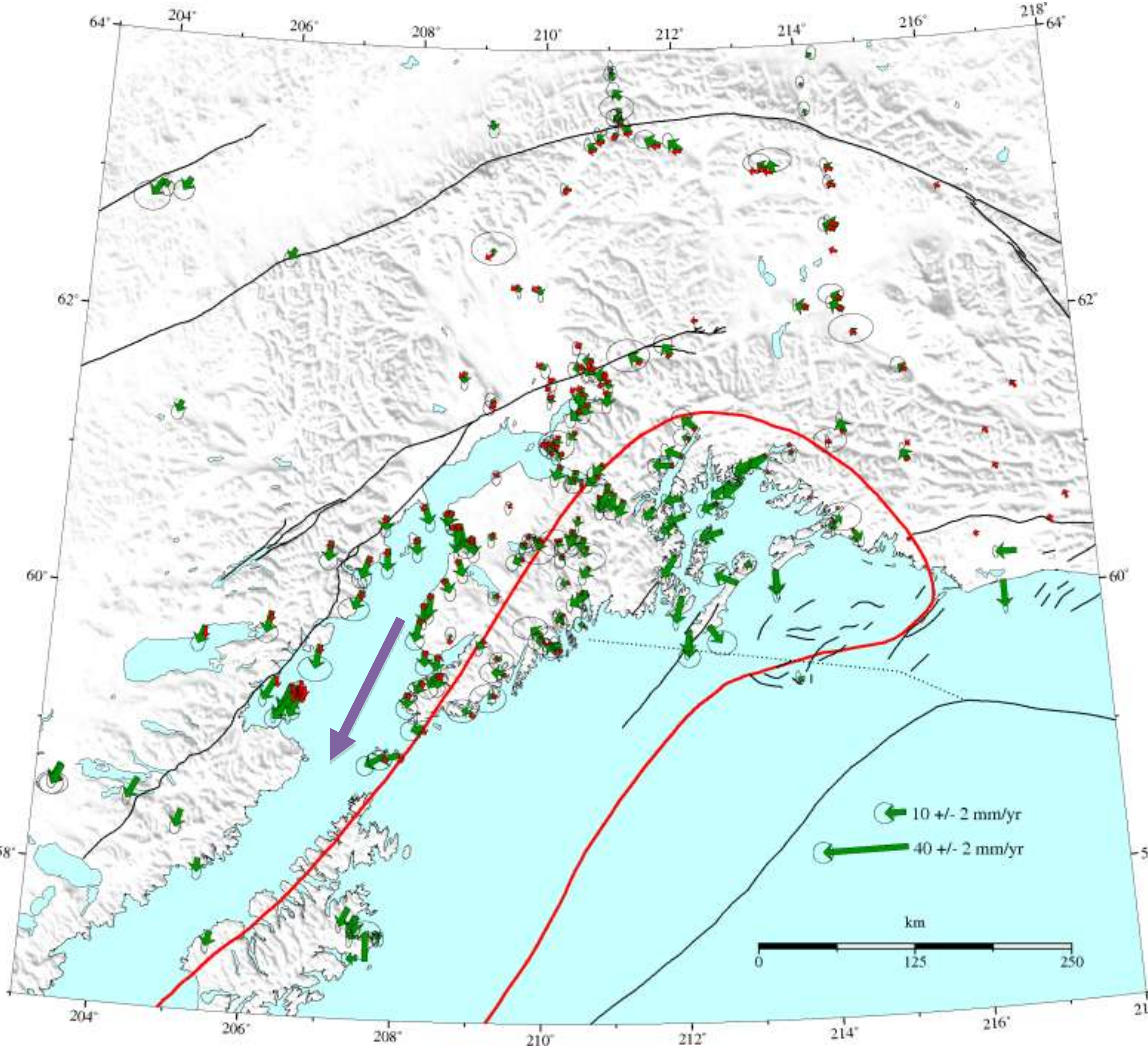
Post-1964 Postseismic Uplift



Cohen and Freymueller (2004)

Suito and Freymueller (2009, JGR)





10 +/- 2 mm/yr
40 +/- 2 mm/yr
km
0
125
250

Knowns and Unknowns

- Can we measure and/or predict vertical motions precisely enough
  - How far into the future?
  - Available models explain the horizontal observations well. Do they explain vertical? Or is there something missing?
- Bedrock vs. soft sediments
  - Sediments self-compact – how fast?
  - Silt-rich tidal flats vs. “old” sediments in town

Project Goals

- Measure vertical motions across Kachemak Bay more precisely
  - Precise enough for useful relative sea level predictions
  - Verify that uplift rates are not uniform in region
- Extend models that work for horizontal motions to explain vertical
- Project future relative sea level change locally
- Combine with response of ecosystems

Continuous GPS sites (CORS)

NINI
X75
NINM
DEEP
W86
STRY
S86
M86
ANPR
AC03
AC06
BRAD
BALD
G86
UNF
BUD
MCCF
N59°54'
N59°42'
B86
HOM
R85
STRM
W152°06'
W151°54'
W151°42'
W151°30'
W151°18'
W151°06'
W150°54'
W150°42'
W150°30'
W150°18'
W150°06'
C103
HEBT
2201
NEAL
GRSI
N59°30'
SELD
SLD1
ST19
SLD3
SLD2
SLD4
Ragged Island
AC35
EBAY
Nuka Island
Outer Island
NUKA
N59°18'
COCO
Image © 2010 TerraMetrics
© 2010 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 Europa Technologies
©2010 Google
59°36'24.13" N 151°05'48.40" W elev 453 m
Eye alt 115.90 km